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THE PEACH REPLANT PROBLEM IN ONTARIO

V. THE RELATION OF PARASITIC NEMATODES TO REGIONAL DIFFERENCES IN SEVERITY OF PEACH REPLANT FAILURE[1]

W. B. MOUNTAIN AND H. R. BOYCE[2]

Abstract

Peach production in Ontario is largely restricted to the Niagara Peninsula and Essex County, areas that are separated by some 200 miles but have a similar climate. The peach replant problem has been much more serious in Essex County than in the Niagara Peninsula. A survey of mature peach orchards showed that *Pratylenchus penetrans* (Cobb, 1917) Sher & Allen, 1953, is considerably more prevalent in peach soils in Essex County than in the Niagara Peninsula. In both areas, orchards that had a previous history of the replant problem had three to four times greater soil population of *P. penetrans* than those with no such history. Soils of finer texture were shown to limit the populations of *P. penetrans*, and the relatively low numbers of this nematode in the Niagara Peninsula appear to result from the influence of the finer soils prevailing in that region. The effect of different soil-particle sizes on the build-up of *P. penetrans* may explain the distribution of the peach replant problem in Ontario.

Introduction

Several workers have reported on the peach replant problem in Ontario. Koch (2) discussed the symptomatology and distribution of the problem and reviewed some of the pertinent literature. Patrick (5) showed that microbial action on the amygdalin fraction of peach root residues resulted in toxicity to living peach roots. Ward and Durkee (8) demonstrated that the highest concentrations of amygdalin occur in the bark of peach roots. Wensley (9) found 14 species of fungi to be facultative parasites on the roots of peach seedlings in the greenhouse. The present authors have studied the relation between numbers of plant parasitic nematodes and intensity of peach replant failure in the two main areas of Ontario in which peaches are grown.

Regional Differences in Severity of the Replant Problem in Ontario

The larger of the peach-growing areas is the Niagara Peninsula, where there are approximately 11,600 acres of peaches; the other area is Essex County with approximately 1800 acres. Other very small peach-growing areas are scattered throughout southwestern Ontario.

According to the survey reported by Koch (2), 65% of questionnaires returned from Essex County indicated that replanted trees were killed or their growth was moderately to severely retarded. During the present investigation the authors observed that approximately 50% of the growers in Essex County experienced marked difficulty in reestablishing peach orchards on the finer-textured soils.

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In the Niagara Peninsula the problem appears to be less serious. An appraisal of the severity of the problem in the Niagara Peninsula was requested from the staff of the Vineland Horticultural Experiment Station. Dr. J. F. Brown replied as follows: "It seems to be the case that the replant problem with peach is of minor importance here. This opinion is based on the fact that very few growers have complained to us about having difficulty in replanting peaches and on the fact that our staff members and the horticultural fieldmen located here have not run into a single really serious replant problem despite the fact that they visit a good many growers in the course of a season." Koch (2) states that "Aboveground symptoms of affected peach replants in Ontario are usually in the form of retarded growth . . ." Therefore, it would be very difficult to determine, without accurate measurements, whether the problem exists in an area. On the other hand, major differences in the severity of the problem should be apparent to trained observers. It is evident that differences do exist between the two areas. The authors have spent considerable time in studying regional differences in the severity of this disease because they believe these may be more important than at first appears.

The two discrete peach-growing areas are some 200 miles apart, have similar climates, and within them the same varieties are grown and similar cultural practices prevail. Yet, in Essex County, difficulty in reestablishing peach has occurred in over 50% of the orchards, whereas in the Niagara district such difficulties, according to Brown, have occurred in considerably less than 5% of the orchards. It appeared that such regional differences in the severity of the disease might provide a key to its solution, and that any explanation of the cause should also explain the distribution of replant failure.

Distribution of Plant Parasitic Nematodes in Relation to Occurrence of the Problem

As Koch (2) has mentioned, the peach replant problem is basically a root-rot disease and, as such, the factor or factors responsible for the condition are essentially soil-borne. These factors apparently build up in the soil during the life of the preceding peach orchard. Furthermore, the unequal intensity of the disease, as indicated in the preceding section, suggests that the soil-borne factors responsible for the trouble are likely to be unevenly distributed. In accordance with this reasoning a survey of mature peach orchards was undertaken to determine whether a characteristic parasitic nematode fauna was associated with the roots of peach trees, and how consistently such a fauna occurs in the two areas.

During 1954 and 1955, soil samples from 167 peach orchards were analyzed qualitatively and quantitatively for their nematode fauna. The average age of the orchards sampled, as nearly as could be determined, was 20 years. Each soil sample consisted of 1 qt. of orchard soil taken from around the feeder roots. During the first season the soil sample was taken from the root zone of a single tree selected at random in each orchard. Subsequently, as an aid to greater accuracy, a composite quart of soil was taken from the root zones

of four trees selected at random in the remaining 70% of the orchards. However, the data obtained by the two sampling methods were found later to be essentially similar. Each soil sample was processed by a modification of Cobb's sieving and decanting procedure by using screens of 35, 100, 200, and 325 mesh. The nematodes removed were identified and counted, and the populations standardized on the basis of 1 lb. of soil. Whenever possible, the following information was obtained at the time of sampling: general condition of the orchard, age of the orchard, soil type, drainage, type of cover crop, and history of replant difficulties.

Fig. 1 shows that only a few parasitic forms were found to be abundant in Ontario peach orchards.

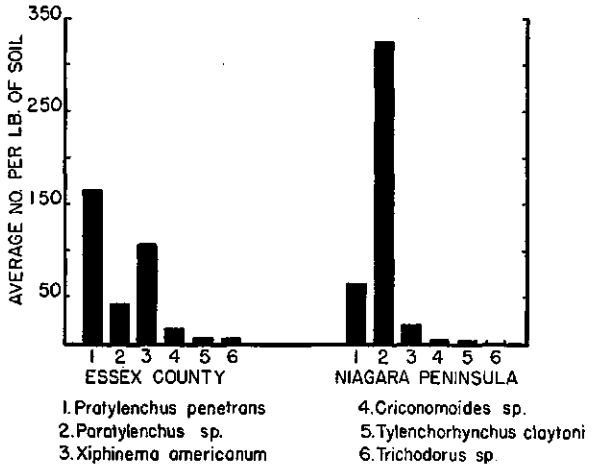

FIG. 1. Occurrence of the major plant parasitic nematodes in 167 mature peach orchards of Ontario.

The most frequently encountered plant parasitic forms were as follows:

Pratylenchus penetrans (Cobb, 1917) Sher & Allen, 1953. Over 99% of *Pratylenchus* identified were of *P. penetrans*. But occasionally *Pratylenchus minyus* Sher & Allen, 1953, occurred.

Paratylenchus sp. Those specimens which have been examined resemble most closely *Paratylenchus projectus* Jenkins, 1956. Other species may occur but, as no study was made of the relationship of this genus to the growth of peach, and in view of the present confused status of the taxonomy of this genus, the authors did not attempt to make specific identifications.

Xiphinema americanum Cobb, 1913.

Criconomoides rusticum (Micoletzky, 1915) Taylor, 1936. A number of specimens from several collections proved to be this species. However, Brown (1) has identified *Criconomoides xenoplax* Raski, 1952, from peach soil at Harrow, and other species may occur.

Tylenchorhynchus claytoni Steiner, 1937.

Trichodorus sp. is not a common nematode in southwestern Ontario and occurred in few orchards.

Species of *Longidorus* and *Rotylenchus* were recovered rarely. As is common in many soils, numerous other spear-bearing forms were encountered. These included many *Dorylaimina*, several species of *Aphelenchoides*, *Aphelenchus avenae*, *Tylenchus filiformis*, other species of *Tylenchus* and *Ditylenchus intermedius*. A list of over 25 genera which have been found in peach soils could be given but such a list would be of questionable value in a work of this nature. The occurrence of many forms could not be correlated with the disease. Most of them are quite common in Essex County, and occur in the same general soil types near the roots of many different crops.

Further reference to Fig. 1 shows that only three parasitic forms are common in peach soils. Relatively large populations of *Pratylenchus penetrans* and *Xiphinema americanum* occur in Essex County, whereas the predominant form in the Niagara Peninsula is *Paratylenchus* sp. Attempts to correlate populations of the three forms with a past history of replant difficulties in each of the orchards sampled indicated that neither *Xiphinema americanum* nor *Paratylenchus* sp. were consistently associated with histories of replant failure, but populations of *Pratylenchus penetrans* were positively correlated with the replant problem and this correlation is shown in Table I.

TABLE I

THE RELATION OF THE DISTRIBUTION OF *Pratylenchus penetrans* TO THE OCCURRENCE OF THE PEACH REPLANT PROBLEM IN THE TWO MAJOR ORCHARD AREAS IN ONTARIO

District	Number of orchards sampled	Per cent of total orchards sampled	Per cent of orchards with a replant history	*Pratylenchus penetrans* per pound of soil	
				Orchards with replant history	Orchards without replant history
Essex County	28	8.2	50.0	213	69
Niagara Peninsula	139	7.7	8.6	200	53

Examination of the data presented in this section shows the following:

(1) The proportion of orchards having a history of replant difficulties was greater in Essex County than in the Niagara Peninsula.

(2) *P. penetrans* was present in large numbers in proportionately more orchards in Essex County than in the Niagara Peninsula. In Essex County, 50% of the orchards sampled contained an average of 200 *P. penetrans* per pound of soil, whereas scarcely 9% of the Niagara orchards had populations as large.

(3) Regardless of the district, there were between three and four times as many root lesion nematodes (*P. penetrans*) in the soil of those orchards having a definite history of replant difficulties as in the soil of orchards where no replant difficulty has occurred.

The Occurrence of the Peach Replant Problem in Relation to the Limiting Effect of Certain Soil Types on *Pratylenchus penetrans*

The authors have established that high populations of *P. penetrans* occur in a greater percentage of orchards in Essex County than in the Niagara Peninsula, despite the similarity in climate and cultural practices. It was thought that differences in the physical characteristics of the soils, as observed during the soil screening process, might be responsible for limiting the numbers of the nematode. In Essex County, many peach orchards are located either on Harrow sandy loam or Fox sandy loam, both of which are relatively coarse soils according to the soil survey of Richards *et al.* (6). In contrast, according to Dr. J. A. Archibald (private communication), well over 80% of the peach soils in the Niagara Peninsula are classified either as Vineland fine sandy loam or Vineland sandy loam, both of which are relatively fine soils.

Sleeth and Reynolds (7) showed that infestation of *Sesbania exaltata* by the root-knot nematode *Meloidogyne javanica* was extremely light when the plant was grown on a fine-textured or clay-loam soil and very heavy in a coarse-textured or loamy-sand soil. Unpublished information by Mountain has shown that corn growing in Harrow sandy loam infested with *Pratylenchus minyus* supported a higher root population than did corn growing in Tuscola fine sandy loam or Brookston clay. In New York State Parker and Mai (4) found that in sour cherry orchards poor growth associated with *P. penetrans* was most evident in light-textured soils.

To determine whether numbers of *P. penetrans* were related to general soil types in Ontario peach orchards, soil samples from all commercial peach nurseries were evaluated for such differences. After the soils had been screened and the populations of nematodes determined, the average population of *P. penetrans* per pound of soil in each of the general soil types was calculated. The data are given in Fig. 2, which shows that the coarse soils contained larger populations of *P. penetrans* than the finer soils which are composed of higher

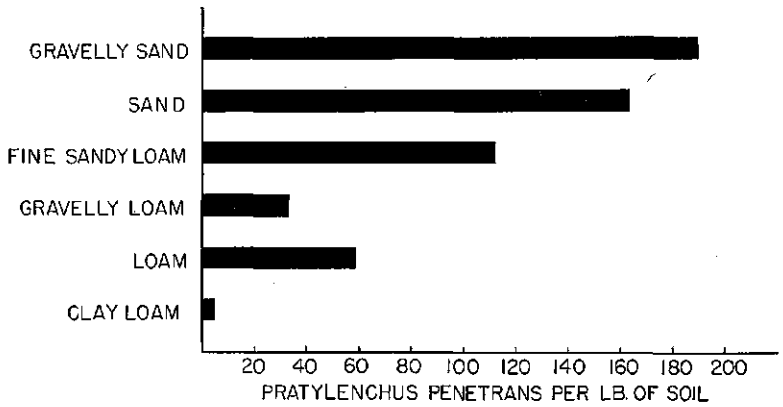

FIG. 2. The relationship between general soil type and the soil population of *Pratylenchus penetrans* in peach nursery soils.

proportions of silt and clay. It appears logical to assume that the lower populations of *P. penetrans* in peach soils of the Niagara Peninsula may be due to higher proportions of finer soil particles.

An experiment was undertaken in the greenhouse to test the assumption developed in the preceding paragraph. Quantities of soil were obtained from a peach orchard at the Vineland Horticultural Experiment Station at depths ranging from 6 to 18 inches. The soil, which is classified as Vineland fine sandy loam, may be regarded as representative of a typical Niagara peach soil and will be referred to in this section as Niagara Soil. By the same method, quantities of soil, classified as Harrow sandy loam and representative of Essex County peach soil, were obtained in the Harrow district and will be referred to in this section as Harrow Soil.

The soils were treated with methyl bromide at a rate of 2 lb. per 75 cu. ft. and then aerated for 1 month at the end of which period living nematodes could not be detected in either soil. Both soils were then inoculated with *P. penetrans*, the inoculum being prepared as follows: Vetch was planted in peach soil for a period of 1 month. At the end of that time, the vetch roots were heavily infested with *P. penetrans*. The roots were removed from the soil, washed, chopped, and added to steamed compost soil. Vetch was then planted in this soil. The nematodes readily penetrated the new vetch roots, and when representative samples of these roots were processed it was found that 98.2% of the nematodes that emerged from them were *P. penetrans*. The remainder were common saprophytes, mainly species of *Rhabditis* and *Eucephalobus*. During an incubation period of 1 month, an average of 2860 *P. penetrans* emerged per gram (fresh weight) of root.

In January 1957, the infested vetch roots were removed from the compost soil, washed, chopped, and mixed. One gram of the root material was mixed with sufficient fumigated Niagara Soil to fill one 7-in. pot which had been steamed previously. Twenty such pots were set up for both the Niagara and Harrow soils with corresponding checks. One Lovell peach seedling (approximately 4 cm. high) was planted in each pot. The initial height of each seedling was recorded. The pots were placed on a greenhouse bench in a random design.

The growth of the seedlings was measured at weekly intervals over a period of 6 weeks. The average net growth for each treatment, plotted at weekly intervals, is shown in Fig. 3. At the end of the experiment, the plants were removed from the soil, the roots washed thoroughly and incubated (10) for a period of 1 month. The only parasitic nematode to emerge from the roots was *P. penetrans* and the populations of this nematode were standardized on the basis of numbers per gram (dry weight) of root tissue. The results are given in Table II.

Samples of the two soils were sent to the Department of Soils at the Ontario Agricultural College for particle size analysis. Later, it became apparent that quite large differences occurred in the sand fraction of the soils and further analyses were carried out. The particle size analyses are recorded in Table III.

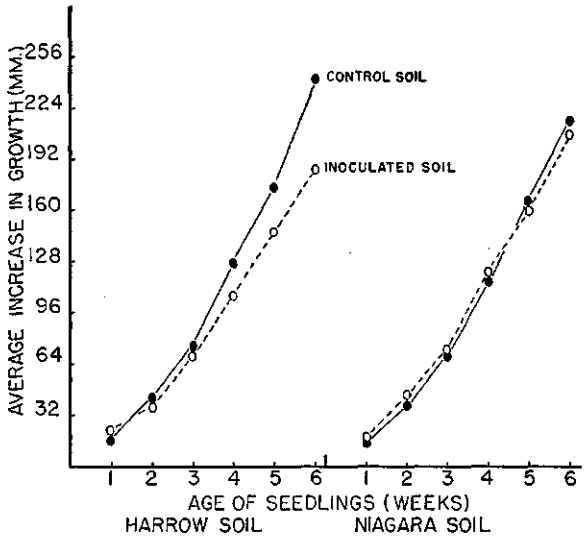

FIG. 3. Comparison of the growth of peach seedlings in nematode-inoculated and in noninoculated soils of the two major peach-producing areas of Ontario.

TABLE II

RELATIVE GROWTH OF PEACH SEEDLINGS AND FINAL POPULATIONS OF *Pratylenchus penetrans* IN ARTIFICIALLY INFESTED SOILS TYPICAL OF ESSEX COUNTY AND THE NIAGARA PENINSULA ORCHARDS

Soil type	Growth of peach seedlings (as % of controls)	*Pratylenchus penetrans*	
		Original inoculum (per pot)	Final recovery (per gram of root)
Harrow Soil	77%	2860	2258
Niagara Soil	97%	2860	877

TABLE III

PARTICLE SIZE OF PEACH SOILS TYPICAL OF ESSEX COUNTY AND THE NIAGARA PENINSULA

Soil	Distribution of soil particles (%)					
	Sand				Silt	Clay
	2.0–0.42 (mm.)	0.42–0.144 (mm.)	0.144–0.044 (mm.)	0.044–0.02 (mm.)	0.02–0.002 (mm.)	Less than 0.002 (mm.)
Harrow	7	58	14	1	7	13
Niagara	1	10	51	12	11	15

The data presented in Tables II and III and Fig. 3 support the following conclusions:

(1) The growth of peach seedlings in nematode-infested Harrow Soil was significantly suppressed by the end of the third week, and the suppression subsequently increased for the duration of the experiment. Only a slight and insignificant suppression of growth occurred in the seedlings in the nematode-infested Niagara Soil.

(2) There were no significant differences between growth of seedlings in the noninfested Niagara Soil and noninfested Harrow Soil.

(3) Although the two soils initially were inoculated with identical numbers of *P. penetrans*, at the conclusion of the experiment scarcely one-third as many nematodes were recovered per gram of peach root grown in Niagara Soil as from those grown in Harrow Soil. There is no doubt that some factor in the Niagara Soil had limited the numbers of *P. penetrans* within the roots.

(4) Physical analyses of the two soils have shown that the sand fraction of the Harrow Soil is much coarser than that of the Niagara Soil. Indeed, 63% of the Harrow Soil consists of particles larger than 0.15 mm. as compared with 11% of the Niagara Soil.

If it be assumed that *Pratylenchus penetrans* is an incitant of the peach replant problem, an explanation for the regional differences in severity of the problem becomes relatively simple. The populations of *P. penetrans* appear to have been limited by the soils of the Niagara area and therefore the nematode has seldom built up to the point where noticeable symptoms on replants would appear.

It is also interesting to recall that not all of the replanted orchards in Essex County have shown symptoms of replant failure. Occasionally the disease is severe in only a portion of a newly replanted orchard. A possible explanation for the variation of the problem in Essex County may be found in studying a soil map of the area. The soils of the peach-growing areas of this county are quite variable. Richards *et al.* (6) have noted that these soils were subjected to strong morainic influences resulting in small stoney ridges occurring among outwash soils giving quite sharp fluctuations in soil type within relatively small areas. In one orchard the authors observed that the soils varied from coarse sand to sandy loam and that replant failure was more severe in the coarse soil. From the data presented, one might predict that the peach replant problem is likely to be most severe on the coarser sands, and somewhat less severe or perhaps even nonexistent on fine sandy loams or silty loams.

Discussion

The rules of proof of pathogenicity which were developed in 1882 by Robert Koch (3) gave bacteriologists a sound and logical procedure for etiological investigations of diseases of man and animals. The fact that the same rules have proved so valuable to plant pathologists in their investigations attest to the sound logic and importance of these postulates.

In the study of root-rot complexes, the word complex suggests an intricate problem because of the possible interaction of many factors in the onset of the disease. The first of Koch's postulates is that there must be a close and consistent association of the organism with the disease, therefore the application of this first postulate should resolve the relative importance of the various potential factors in the etiology of a root rot. Laboratory procedures may demonstrate a number of reactions which can cause root degeneration, but if a close association between such a reaction and the disease, as it actually occurs in nature, has not been shown, the basis of this reaction in terms of reality can never be established. The mechanism or organism remains a potential or so-called contributing factor and the problem continues to appear vague and complex.

The authors believe the only way that the peach replant problem or any root rot can be clarified is by concentrating on those factors which are closely associated with the disease. Early in this investigation, the authors found some 25 genera of nematodes in peach soils. All of these were potential factors in the peach replant problem and the literature shows that many of them do affect the growth of plants. Initially, then, the nematode picture appeared to be very complex. But the application of Koch's first rule of proof indicated that only *P. penetrans* should be a potential cause of the failure of replanted peach trees. The authors are convinced that the data are adequate to postulate that the close association between the distribution of the peach replant problem and high populations of *P. penetrans* would seem to justify further investigation of the host–parasite relations involved.

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In the very early phases of this work, the identification of the various nematodes encountered was confirmed by Mr. Gerald Thorne, formerly Senior Nematologist, U.S. Department of Agriculture.

The authors would like to acknowledge the assistance of Professors N. R. Richards and L. R. Webber of the Soils Department, Ontario Agricultural College, for conducting soil analyses.

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